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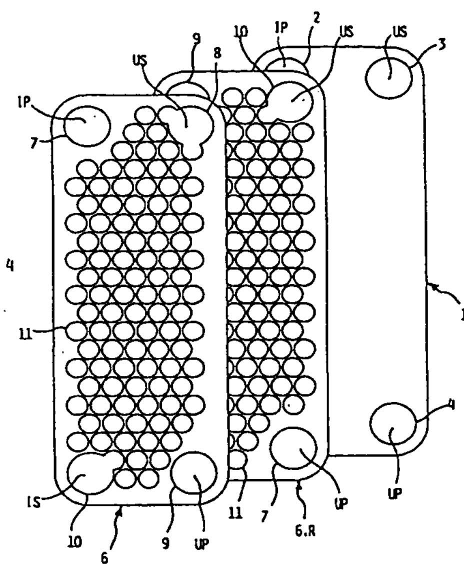
(54) Device for heat and/or matter exchange

(57) A heat and/or matter exchanger for fluids, comprising a plurality of flat plates (1,13) and a plurality of spacing elements (6,6.R; 22,22.R), said flat plates (1,13) together with said spacing elements (6,6R; 22,22R) defining one or more primary heat and/or matter exchange chambers for the flowing of a primary fluid; said flat plates (1,13) together with said spacing elements (6,6.R; 22,22.R) also defining one or more secondary heat and/or matter exchange chambers for the flowing of a secondary fluid. The primary chambers are connected between themselves and with the outside by a plurality of primary openings (IP,UP) and are inserted in alternate sequence in the secondary chambers, which are connected between themselves and with the outside by a plurality of secondary openings (IS,US). The exchanger according to the present invention is characterized in that at least one of said primary and/or secondary chambers comprises two or more perforated flat plates (6,6.R) acting as spacing elements, each one with staggered through openings (11), so that the overlapping of said perforated flat plates forms contact zones (11.A) and through gaps (11.B) where the contact zones (11.A) ensure both a thermal and mechanical continuity between the perforated flat plates (6,6.R) and the through gaps (11.B) put in intercommunication at least some empty spaces obtained by the through gaps (11) inside each perforated flat plate.

FIG. 4



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Description

This invention refers to a device for heat and/or matter exchange between substances in a liquid, vapour or gaseous state.

Plate-type heat exchangers are already known. A most diffused and consolidated version of said exchangers consists of metal plates packed together to define a certain number of parallel ducts.

Two fluids, which may be called primary and secondary fluid, are flown through said ducts and thermal exchange takes place between the two, if the primary fluid flows in the ducts of even number then the secondary fluid will flow in the ducts of odd number, so that in each duct one of these two fluids can exchange heat with the other through the plates defining the duct itself.

Adequately shaped gaskets restrain each one of these two fluids in their relevant ducts and act as a spacer between a flat plate and its subsequent one.

Some of the plates mentioned above have holes located in appropriate positions, usually on their corners, through which the fluids to be distributed into the ducts flow, according to the known state of the art, the availability of holes or not, at least in some plates, allows a parallel arrangement of the ducts flown by the same fluid or to create paths consisting of packs of parallel ducts, connected in series between themselves.

The plates through which a thermal exchange takes place usually have a corrugated surface, since a set of parallel channels in a herring-bone pattern is obtained on them by drawing of the plates, the plates are packed together placing them one to the right and one overturned, and so on, so that the above channels on a plate intersect the ones of a subsequent plate; availability of said channels improves heat exchange, in dependence both from the actually increased exchange surface and above all from the increased turbulence of the fluids being forced to cover a sinuous path within the channels.

A further purpose of said channels is to allow a contact between two subsequent plates in evenly distributed small zones close to each other, so that likely pressure differences between the two fluids, even significant ones can be borne by the plates without deformations; thus, all efforts are discharged on two big end plates closing the plates pack, locked by tension rods.

Other plate-type heat exchangers are also known, where said plates to form the ducts are smooth Said exchangers are provided with metal nets substantially filling the duct , but not preventing the fluids from flowing through the net mesh to allow the required turbulence and both the mechanical and thermal contact between a flat plate and the following one. As for the rest, said exchangers do not substantially differ from the previous ones.

Finally, other heat exchangers are known where the draw-flared edges of each flat plate do not require any gaskets since, in this instance, sealing can be warranted by braze-welding after inserting each flare-edged flat plate in the subsequent one.

A main advantage of plate-type heat exchangers is the opportunity of obtaining highly extended exchange surfaces in spite of small overall dimensions, and their extremely simple way to obtain various types of series-parallel paths, even most complex ones, simply alternating a few plate types in the exchanger composition according to an appropriate sequence.

Plate-type exchangers using rubber gaskets cause some inconveniences, such as a difficult fully automatic assembly and insufficient reliability when using toxic or corrosive fluids, specially under high pressure conditions.

Also welded versions cause some restrictions, since flared plate edges do not usually match exactly enough to allow the use of brazing alloys to warrant a highest mechanical and chemical strength, the latter require in fact a most precise matching between the joining parts. Therefore, significant applications such as ammonia-operated refrigerating systems (either absorption or mechanical compression types) have practically no application for plate-type exchangers.

In general, it is the object of this invention to solve the above problems related to the devices of known type and provide a device suitable for heat and/or matter exchange, which performs well, allows an easy compact execution, is low cost and offers a most versatile application.

Under this frame, a first object of this invention is to provide a device for heat and/or matter exchange, which can be executed using substantially flat modular elements obtained by simple mechanical processes.

A second object of this invention is to provide a device for heat and/or matter exchange, using a minimum selection of said modular elements, for use in a repetitive manner and different quantity according to each case, resulting in a extremely simple automatic assembly.

A third object of this invention is to provide a device for heat and/or matter exchange, which, in respect to the known devices of equal capacity, is more compact and has reduced dimensions.

A fourth object of this invention is to provide a device for heat and/or matter exchange where gravitational films can be formed in a simple low-cost manner.

Said objects can be obtained according to this invention by providing a device for heat and/or matter exchange comprising the characteristics reported in the annexed Claims, which are integral part of this invention.

Further objects and advantages of this invention will be apparent from the following detailed description and annexed drawings, which are supplied by way of explanatory but not limiting example only, where:

- Figs. 1 to 8 show suited components and assemblies to manufacture a heat and/or matter exchanger according to this invention;
- Figs. 9 to 18 show the components and assemblies

of a compact device for heat and/or matter exchange according to this invention.

In the above figures, where the parts of no interest for the description of the device are omitted, all elements are shown upright.

Fig. 1 shows a generic separating flat plate between two subsequent ducts of a plate-type exchanger according to this invention. This plate, indicate as a whole with 1, shows:

- a first opening, indicated with IP, defined by a through hole 2, for the flowing of a primary fluid to be *distributed* in the ducts pertaining to a primary exchanger circuit;
- a second opening, indicated with US, defined by a through hole 3, for the flowing of a secondary fluid to be *collected* from the ducts pertaining to a secondary exchanger circuit;
- a third opening, indicated with UP, defined by a through hole 4 for the flowing of said primary fluid to be *collected* from the ducts pertaining to the primary exchanger circuit;
- a fourth opening indicated with IS, defined by a through hole 5 for the flowing of said secondary fluid to be *distributed* in the ducts pertaining to the secondary exchanger circuit.

Fig. 2 shows a generic perforated flat plate whose function is to space and support the plates shown in Fig. 2 as well as to distribute fluids and generate fluid turbulence.

As it can be seen, said perforated plate indicated with 6 shows the same openings defined in Fig. 1, identified with the same references IP, US, UP and IS, which are defined by the through holes 7, 8, 9 and 10, respectively. Plate 6 also has a through holes array indicated with 11, with holes arranged in a substantially even manner all over the surface. The through holes array 11 is adequately stopped near the through holes 7 and 9, whereas it intersects the through-holes 8 and 10.

Fig. 3 shows a perforated flat plate 6.R similar to the one of Fig. 2, but rotated the other way round by 180°; references IP, US, UP and IS identify the same openings as defined with reference to Fig. 1, which are now defined by the through holes 9, 10, 7 and 8, respectively due to the plate rotation. Moreover, also the already mentioned through holes array 11 is visible.

Fig. 4 shows assonometrically the packing criteria for the plates of Figs. 1, 2 and 3, in order to perform a generic portion of a plate-type exchanger according to this invention. Said Fig. 4 shows the perforated flat plate 6 of Fig. 2, the perforated flat plate 6.R, of Fig. 3 and the separating flat plate 1 of Fig. 1.

Fig. 5 shows a front view of a generic portion of a heat and/or matter exchanger according to this invention; as it can be seen, a perforated flat plate 6 is shown overlapping a perforated flat plate 6.R, so that the through hole arrays 11 related to said plates 6 and 6.R can define the through paths, some of them indicated with 12. In the specific instance of Fig. 6, the through paths 12 relate to a fluid coming from the opening IS and directed to opening US.

Fig. 6 shows more in detail some of the countless paths 12, which are defined by the through holes 11 of the perforated flat plates 6 and 6.R overlapping each other. In this Fig. 6 reference 11.A indicates one of the contact zones between the perforated flat plates 6 and 6.R, whereas 11.B indicates one of the openings resulting from the staggered location of the through hole arrays 11 on the perforated flat plates 6 and 6.R.

As it is apparent from Fig. 6, the contact zones 11.A ensure a mechanical and thermal continuity for the plates 6 and 6.R, whereas the openings 11.B cause intercommunication between some empty spaces created by the through holes 11 within each perforated flat plate 6 and 6.R. An embodiment of the device according to this invention, in particular, has practically all empty spaces created by the holes 11 in the plates 6 and 6.R intercommunicating through the opening gaps 11.B.

With a view to obtain a heat and/or matter exchanger according to this invention, the plates previously illustrated are packed together in such a way to define a certain number of parallel ducts.

To this purpose, Fig. 7 is a side view showing in a general section A - A of Fig. 5 the ducts sequence that can be obtained with an alternated composition consisting of a separating flat plate 1 of Fig. 1, a perforated flat plate 6 of Fig. 2, a perforated flat plate 6.R of Fig. 3, a further separating flat plate 1, and so on. Moreover, this figure also shows the through hole arrays 11 and the opening gaps 11.B.

Fig. 8 is similar to Fig. 7; however, in this instance the first and third ducts (from the left) are obtained each one of them using two perforated plates 6 and two perforated plates 6.R; Fig. 8 clarifies how each duct of the heat and/or matter exchanger device according to this invention may actually consist of an undetermined number of plates, which may even differ from a duct to another.

The device according to this invention, whose components are shown in the Figs. 1 to 8, operates as described hereunder.

As said above, the perforated flat plate 6.R of Fig. 3 consists in practice of the perforated flat plate 6 of Fig. 2 rotated by 180° over its plane (i.e. around an axis perpendicular to the plate itself), locating the through holes 11 in said perforated flat plate 6 in an adequate asymmetric position to the plate centre and overlapping the perforated plates 6 and 6.R so that the axis of the holes defining the openings IP, US, UP and IS may be in line with each other, said through hole arrays 11 will overlap each other in a staggered pattern as shown in Fig. 5, obtaining the through gaps 11.B shown in Fig 6. Wide contact zones 11.A are maintained anyway between the two plates 6 and 6.R. Due to the contact zones 11.A, either peripheral or within the through hole arrays 11, the plates 6 and 6.R can be solidly joined together by

gluing, braze-welding or other known techniques to obtain a mechanically strong and thermally conductive structure.

Assembly procedure can go on indefinitely as schematically shown in Fig. 4, alternating the perforated flat plates 6 and 6.R and placing two separating flat plates 1 of Fig. 1 both at the beginning and at the end of the pack formed by said perforated flat plates 6 and 6.R. Thus, ducts can be obtained wherein a fluid (for instance the secondary fluid) can freely flow from opening IS to opening US along countless through paths, as shown in Fig. 5. However, said fluid cannot outflow outside nor mix with the primary fluid flowing through the openings IP and UP.

If the duct according to the above composition is followed by another where the perforated flat plates 6 and 6.R are tilted by 180°, independently from the horizontal or vertical axis (thus obtaining a specular figure against the one shown in Fig. 5), then in this further duct the primary fluid will be free to flow from opening IP to opening UP, but unable anyway to outflow outside or mix with the secondary fluid flowing through the openings IS and US.

The separating flat plate 1 generally shown in Fig. 1 can also be considered as the most external plate of a heat exchanger, in this instance it is possible to clamp some mouthpieces (for instance like the mouthpieces indicated with 51 in Fig. 19) in line with the through holes 2, 3, 4 and 5.

Through these mouthpieces a primary fluid can be introduced in the exchanger through the opening IP and expelled through the opening UP, similarly, a secondary fluid can be introduced through the opening IS and expelled through the opening US.

As it can be seen from the Figs. 1, 3, 4 and 5, said openings IP, UP, IS and US go on through all the plates 1, 6 and 6.R; however, as already proven, the above primary and secondary fluids cannot reach a mutual contact, on the contrary a thermal contact between the fluids flowing in parallel and in counterflow is reached through the separating flat plates 1. On the other hand, as it can be apprehended, more complex circuits having groups of ducts arranged in parallel and groups in series in respect to other duct groups can be easily obtained according to the present state of the art (for instance, using separating plates similar to 1, where one or more through holes 2, 3, 4, 5 are missing).

The perforated flat plates 6 and 6.R may have any thickness, even a very thin one, since only the outside dimensions of the device and the thickness of the same perforated flat plates can have practical restrictions; the same applies for the quantity of said plates in a single gap.

The separating flat plates 1 shall have a consistent thickness to withstand likely pressure differences between the two fluids where thermal exchange occurs and between them and the environment outside.

As shown in figs. 7 and 8, it is possible to obtain ducts consisting of a variable number of perforated flat plates 6 and 6.R, since heat transmission between both fluids is ensured as all perforated flat plates 6 and 6.R within the same duct have heat bridges formed by the contact zones 11.A.

Finally, it should be noted that the perforated flat plates 6.R do not necessarily need to be obtained only through 180° rotation of the perforated flat plates 6; this represents in fact a considerable manufacturing advantage, however, to the purpose of the exchanger's operation the plate 6.R could be conformingly different (for instance due to the design of the through holes array 11 and/or for its thickness) of the perforated flat plate 6. Moreover, due to thermofluid-dynamic reasons, it is generally appropriate to have the through holes arrays 11 designed as a function of the fluid flowing through them therefore, as a general rule, the ducts in one same exchanger wherein the primary fluid is flowing may consist of perforated flat plates 6 and 6.R, which differ for their design from the through holes array 11, and for their thickness and number from the corresponding perforated plates 6 and 6.R related to the secondary fluid. In addition, due to thermofluid-dynamics reasons, it can be of advantage to have the through holes array 11 provided with holes of different form and distributed in an uneven pattern.

The sole conditions required is to obtain the above through gaps 11.B and contact zones 11.A by overlapping a perforated flat plate 6 to a perforated flat plate 6.R.

Both the flat plates 1 and perforated flat plates 6 can be either metal or heat conductive ceramic material.

The ducts for primary and secondary fluids circulation can be sealed by braze-welding some plates 1 and 6 (if metal) or using sealants or elastomeric gaskets. An optional procedure is to coat the plates surfaces, e.g. with polytetrafluorethylene, then seal them by sintering the material deposited on the plates.

The device according to this invention as described above with reference to Figs. 1-8 can be immediately applied as a heat exchanger between a primary fluid distributed in the primary chambers (odd number) through the openings IP and UP and a secondary fluid distributed in the secondary chambers (even number) through the openings IS and US. Heat exchange between the primary and the secondary fluids is obtained through the separating flat plates 1.

The use of the perforated flat plates 6 and 6.R acting as spacing elements between the separating plates 1 to form the primary and secondary chambers offers many advantages in respect to the devices already known, since:

1) Fluids turbulence is intensified by the through gaps 11.B, with improvement of the thermal exchange performance;
2) assembly of the whole device using a few modular elements (separating plates 1 and perforated flat plate 6 conveniently oriented);
3) automated assembly of the device;

4) desired thickness of primary chambers and secondary chambers obtained by simply overlapping a proper number of plates 6;

5) thermodynamic processes can be affected as required through simple manufacturing parameters of the plates 6, namely their number, holes 11 diameter and pitch.

For the man skilled in the art it will also be obvious that the device described with reference to figs 1-8 can also be used as a matter exchanger for fluids.

A heat and matter exchanger device of particular advantage according to this invention, is also described with reference to Figs. 9-18. For clarity's sake such a device will be described with reference to a distiller and rectifying device; on the other hand, as it will become apparent later, it is clear that the inventive idea can also be applied to other matter exchange devices (either with or without heat exchange).

As it will be seen, also with a view to obtain a distiller device according to this invention, several plates adequately shaped are packed together to define a certain number of parallel ducts wherein a fluid mixture to be distilled, a refrigerating fluid, a heating fluid or a vapour mixture to be rectified can flow through.

Fig. 9 shows a generic end or separating flat plate, indicated with 13, of the compact distiller and rectifying device according to this invention, such a plate 13 showing:

- an opening IL defined by a hole 14 for the flowing of a rich fluid mixture to be distilled, for *distribution* to a number of ducts forming distillation chambers;
- an opening IR defined by a hole 15 for the flowing of a refrigerating fluid to be *distributed* in a number of ducts for a refrigerating fluid;
- an opening UV defined by a hole 16 for the flowing of a distilled vapour, to be *collected* from said distillation chambers ducts;
- an opening UR defined by a hole 17 for the flowing of said refrigerating fluid, to be *collected* from the refrigerating fluid ducts;
- an opening IV defined by a hole 18 for the flowing of a very rich mixture in a vapour state to be rectified, for *distribution* to the distillation chamber ducts;
- an opening UE defined by a hole 19 for the flowing of a heating fluid, to be *collected* from the heating fluid ducts;
- an opening UL defined by a hole 20 for the flowing of a poor liquid mixture, to be *collected* from the distilling chamber ducts;
- an opening IE defined by a hole 21 for the flowing of above said heating fluid, to be *distributed* to the heating fluid ducts.

Figs. 10 and 11 show some perforated flat plates 22 and 22.R, called "rectify side" in the following, being used to form the ducts wherein a mixture to be distilled is flowing; as it will be seen, by packing two or more "rectify side" flat plates 22 and 22.R we obtain the distillation and rectifying ducts wherein the mixture to be distilled and/or rectified is circulating, as it will be apparent from the following description.

The plate 22 of Fig. 10 shows the same openings already highlighted in fig. 9, indicated with the same letters IL, IR, UV, UR, IV, UE, UL and IE, defined by the through holes 23, 24, 25, 26, 27, 28, 29 and 30, respectively; moreover, also an even through-holes array 31 substantially spread over the whole surface of the plate 22 can be seen, the through holes array 31 is adequately interrupted near the through holes 24, 26, 28 and 30, whereas it intersects the through holes 23, 25, 27 and 29 (specifically concerning the through holes array 31 both holes 31.A and 31.B intersecting the through holes 23 are highlighted); finally, 32 indicates a boiling zone of the mixture to be distilled, 33 an adiabatic rectifying zone and 34 a refrigerating rectifying zone; the reason for such a denomination will become apparent later.

Fig. 11 shows with 22.R a "rectify side" perforated flat plate similar to reference 22 in fig. 10, which is rotated by 180° in respect to the latter, the letters IL, IR, UV, UR, IV, UE, UL and IE identify the same openings already defined in fig. 10, which are now defined by through-holes 27, 28, 29, 30, 23, 24, 25 and 26, respectively due to plate rotation, also the through holes array 31 (whose holes 31.C and 31.D intersecting the opening 27 are particularly highlighted), as well as the above boiling zone 32, adiabatic rectifying zone 33 and refrigerating rectifying zone 34.

Figs. 12 and 13 show some "exchanger side" perforated flat plates 35 and 35.R, which are used to form the ducts where the heating or cooling fluids for the mixture to be distilled are flowing, as it will be seen, the "exchanger side" perforated plates 35 and 35.R are suitable elements to form the thermal exchange ducts by packing two or more specimen, wherein the fluids due to cause a partial boiling of the fluid mixture to be distilled or a partial vapour condensation of the mixture to be rectified are circulating.

The "exchanger side" perforated flat plate 35 of Fig. 12 shows with the same letters IL, IR, UV, UR, IV, UE, UL and IE, the same openings as defined in fig. 10, delimited by the through holes 36, 37, 38, 39, 40, 41, 42 and 43, respectively; moreover, in line with the positions of the boiling zone 32, of the adiabatic rectifying zone 33 and of the refrigerating rectifying zone 34 identified in Figs. 10 and 11, three holes arrays are indicated, namely:

- a heating fluid through-flow array 44 (adequately interrupted near the opening holes 40 and 42, while intersecting openings 41 and 43);
- a neutral array 45 (that does not intersect any openings, but is connected outside by breathing openings 47);
- a refrigerating fluid through-flow array 46 (adequately interrupted near the openings 36 and 38,

while intersecting the openings 37 and 39).

In Fig 13, a perforated flat plate 33.R is represented similar to the one shown with 35 in Fig. 12, however rotated by 180° in respect to it, the letters IL, IR, UV, UR, IV, UE, UL and IE identify the same openings already defined in Fig. 9, which due to the plate rotation are defined in this case by the through holes 40, 41, 42, 43, 36, 37, 38 and 39, respectively. The figure also shows the same holes arrays identified in fig. 12 and the breathing openings 47 as well.

Fig. 14 shows assonometrically the packing criteria related to the plates shown in Figs. 9, 10, 11, 12 and 13, to represent a generic portion of the distiller and rectifying device, comprising the ducts for circulating the mixture to be distilled and the ducts for circulating the mixture heating or cooling fluids.

Said Fig. 14 shows a "rectify side" perforated flat plate 22, a "rectify side" perforated flat plate 22.R, a separating flat plate 13, an "exchanger side" perforated flat plate 35, an "exchanger side" perforated flat plate 35.R plus a separating flat plate 13. Moreover, the usual openings IL, IR, UV, UR, IV, UE, UL and IE are shown in the same position for each said plate.

Fig. 15 shows a front view of a general portion of the distiller and rectifying device embodiment according to this invention, where a "rectify side" perforated flat plate 22 overlapping a "rectify side" perforated flat plate 22.R as well as the boiling zone 22, the adiabatic rectifying zone 33 and the refrigerating rectifying zone 34 can be seen; moreover, openings IL, IR, UV, UR, IV, UE, UL and IE are also indicated, whereas other elements whose identification is now clear have been omitted.

Fig. 16 shows an "exchanger side" perforated flat plate 35 of Fig. 12, overlapping an "exchanger side" perforated flat plate 35.R of Fig. 13, as well as

- the heating fluid through-holes array 44, whose position is in line with the above boiling zones 32 of Fig. 15;
- the neutral holes array 45, in line with the adiabatic rectifying zones 33 of Fig. 15;
- the refrigerating fluid through-holes array 46, in line with the refrigerating rectifying zones 34 of Fig. 15;
- the breathing openings 47,
- openings IL, IR, UV, UR, IV, UE, UL and IE.

Fig. 17 shows according to a section along the axis A - A of fig. 15 a duct provided for circulating the fluid to be distilled and another duct for circulating the heating or cooling fluids; Fig. 17.A represents an enlarged detail of fig. 17.

Therefore, these figures represent a possible sequence of "rectify side" perforated flat plates 22 and 22.R forming a distiller and rectifying duct 48, and a possible sequence of "exchanger side" perforated plates 35 and 35.R forming a heat exchange duct 49; between these two sequences a separating flat plate 13 is located between the distiller duct 48 and the thermal exchange duct 49.

Fig. 17 also shows the distiller duct 48 with the boiling zone 32 of the mixture to be distilled, the adiabatic rectifying zone 33, the refrigerating rectifying zone 34; viceversa, the thermal exchange duct 49 shows the heating fluid through-holes array 44, the neutral holes array 45 and the refrigerating fluid through-holes 46.

Fig. 18 shows assonometrically a possible embodiment of a compact distiller and rectifying device according to this invention, which is indicated with 50.

Said device 50 comprises an undefined number of distiller ducts in alternate sequence to an equal number of thermal exchange ducts, which are divided by separating plates as previously described; Fig. 18 also shows the repeatedly cited openings IL, IR, UV, UR, IV, UE, UL and IE, defined by the mouthpieces 51; the arrows 52 show either the inlet or outlet flows of said mouthpieces 51.

The operating procedures and advantages of the compact heat and/or matter exchange device according to this invention will now be described showing some preferred but not exclusive embodiments, in the instance of a distiller and rectifying device, description will be restricted to a separation example of two instead of more substances from a single fluid mixture.

As already said, "rectify side" perforated flat plates 22 and 22.R shown in Figs. 10 and 11 are the suitable elements, packed to two or more specimens, to form both the distiller and rectifying ducts 48 of Fig. 17 where the mixture to be distilled and/or rectified will be circulated, whereas "exchanger side" perforated plates 35 and 35.R shown in fig. 12 and 13 are the right elements packed to two or more specimen to form the thermal exchange ducts 49 of fig. 17 where the fluids causing a partial boiling of the liquid mixture to be distilled or a partial vapour condensation of the mixture to be rectified or both said fluids will be circulated, with no possibility for them to reach a mutual thermal or material contact.

The distiller and rectifying ducts 48 and thermal exchange ducts 49 are divided by the separating flat plates 13 of Fig. 9; either the former or the latter or both the separating flat plates 13 can be provided with the mouthpieces 51 of Fig. 18.

Let us now describe some embodiments of the device according to this invention and other possible devices based on the same inventive principle Each device, unless otherwise stated, consists of an undefined number of distiller and rectifying ducts 48 in alternate sequence with thermal exchange ducts 49, as described above.

COMPLETE DISTILLER AND RECTIFYING DEVICE

In all distiller and rectifying ducts 48 as shown in the front view of Fig. 15, a rich fluid mixture to be distilled enters the opening IL, the distilled vapour is expelled out of the opening UV and the poor fluid mixture is expelled

out of the opening UL, during this distiller and rectifying process the opening IV is not used so it is closed to the outside, for instance in line with its relevant mouthpiece 51 of fig. 18.

At the same time, in all thermal exchange ducts 49 shown in the front view of Fig. 16 a refrigerating fluid enters the opening IP and is expelled out of the opening UR, while a heating fluid enters the opening IE and is expelled out of the opening UE.

The device appears to be split from bottom to top in three zones as follows :

I - Boiling and distilling zone

Boiling and partial vaporization of the fluid mixture expelled from IL occur In the boiling zones 32 of Fig. 15 through heating fluid circulation in the heating fluid through-holes array 44 of Fig. 16; as a result, the fluid residue depleted of its more volatile substance is expelled out of the opening UL, while the vaporized portion raises to the adiabatic rectifying zone 33 to meet in counterflow the rich liquid mixture entering the opening IL. It should be noted that the liquid mixture from IL drips by gravity alone through a very uneven path formed by the set of through gaps (11.B, Fig. 7), being interrupted by the contact zones (11.A, Fig. 6) and also hindered by the vapour generated from boiling; therefore, if the "rectify side" perforated flat plates 22 and 22.R are adequately designed, the descent can be slow enough to let a sufficiently leaned out mixture reach the opening UL.

II - Adiabatic Rectifying Zone

Both the distilling and rectifying ducts 48 can be wide enough and with a sufficient number of "rectify side" perforated flat plates 22 and 22.R to hinder the fluid mixture from the opening IL to flood said ducts, but causing it to flow along the surfaces of said "rectify side" perforated flat plates 22 and 22.R. The likely trend of said rich liquid mixture to collect in streamlets instead of wetting said surfaces is continuously opposed as said downflowing mixture is forced all the time to change its path in line with the contact zones 11.A and the through gaps 11.B. Thus, we obtain a rectification based on the gravitational film principle, avoiding anyway any inconveniences of the known state of art.

As an alternative, if it proves of advantage for the specific application process, nothing will hinder the through holes arrays 31 of the "rectify side" perforated flat plates 22 and 22.R to have some holes in this zone, which must be small enough to slow down the fluid mixture downflow and force vapour gurgling through it.

Therefore, in the adiabatic rectifying zone 33 of Fig. 15 the downflowing fluid will be pre-heated taking heat from the upflowing vapour, changing balance concentrations of the substances in the mixtures. As a result the liquid mixture will heat up and release some of its more volatile matter to vapour, whereas the vapour will cool down and release some of its less volatile matter to the fluid. This means an "adiabatic" process, in the sense that heat exchanges occur between the liquid and the vapour phases, however, this will not occur with the fluids outside the distilling and rectifying ducts 48.

In line with the adiabatic rectifying zones 33, the ducts of thermal exchange 49 have neutral hole arrays 45, which are not flown by any fluid, whose purpose is to ensure a structural continuity to the whole device. Said neutral hole arrays 45 are connected outside through breathing holes 47, which are adequate to avoid pressure increases or evacuate the gases eventually forming during the device welding stage.

III - Refrigerating Rectifying Zone

When the vapour overcomes opening IL it enters the refrigerating rectifying zone 34, where a further vapour cooling occurs through a cooler fluid circulating in the thermal exchange duct 49; following this last vapour cooling, a nearly total condensation of the less volatile residues is distiller available in the vapour, whereas the more volatile substance, practically pure, is expelled out of the opening UV; purification process is easy since also in this refrigerating rectifying zone 34 the downflowing condensate is forced to intimate contact with the rising vapour for the same reasons as for the adiabatic rectifying zone 33. Moreover, path uneveness will capture likely condensate droplets entrained by the vapour.

It has been pointed out that the distilling and rectifying ducts 48 should be wide enough to avoid flooding of the rich liquid mixture expelled out of the opening IL. Taking this need into account, if the openings IL were intersected by the through holes array 31 both in the upper and lower sections of its perimeter, it would be possible for all the rich fluid mixture from outside the distiller and rectifying device to be drained by the initial distilling and rectifying ducts 48 it meets and flood them, whereas the subsequent ones would not be fed, for this reason and with reference to the Figs. 10, 11 and 15 it is appropriate for the through holes array 31 to intersect the opening IL only in line with the holes 31.A, 31.B, 31.C and 31.D, which are all located in line with the perimeter upper half of the opening IL. Thus, the rich fluid mixture distributed by the opening IL shall flood the lower half of said opening IL before flowing down to the distilling and rectifying duct 48 and overflow said opening IL all over its length, without being able to feed preferentially the initially met distilling and rectifying ducts 48 .

It was also said that during the above distiller and rectifying process the opening IV is not used. Actually, it can be used in special instances where the process does not only require a relatively cold and extremely pure vapour out of the more volatile substance, but also requires warmer vapour easier to condense at low pressure, or anyway a relatively not very rich vapour. In this instance, said vapour can be tapped off the opening IV directly from the boiling zones 32.

It should be noted, with reference to vapour tapping from the opening IV, that said opening IV in line with the distilling and rectifying ducts 48 is defined by the same holes defining the opening IL. Therefore, as it will be apparent from Fig. 16, it communicates with the distilling and rectifying ducts 48 on the low side only, representing a effectivehindrance within the opening IV itself to the entry of the rich fluid mixture dripping from the opening IL.

Finally, it should be noted that since there is no foreseen thermal exchange with the outside (nor pressures to be borne, with the exception of the separating end flat plates 13); the "rectify side" perforated flat plates 22 and 22.R may also not be made with a material with a special thermal conductivity or mechanical strength; in particular, it is not necessary for said plates to be made with metal, as they can be of any other material suitable for said purpose, such as specific kinds of ceramics or synthetic material.

It is obvious that the above manufacturing criteria may also be used to a partial extent to manufacture less complex devices than described above without departing from the innovative idea.

By way of example we are now describing some embodiments of the device according to this invention, where only some of the functions, processes or elements described above are used.

COMPLETE RECTIFYING COLUMN

In this case reference is made to Fig. 15, which remains unchanged, with the exception of the opening IE and UE that are not used and consequently closed with respect to outside access. Through the opening IV a very rich mixture in its vapour state enters the device coming from an appropriate vapour generator located outside the device. A rich fluid mixture to be distilled enters as above through the opening IL while the poor fluid mixture and the previously rectified vapour go out from the openings UL and UV.

Since the device does not need to bring the mixture to be distilled at boiling point, only the thermal exchange ducts 49 will circulate the refrigerating fluid through the through holes array 46, whereas the remaining ones only have a structural function.

ADIABATIC RECTIFYING COLUMN

Reference is even in this case made to Fig. 15, which remains unchanged, with the exception of the openings IE, UE, IR and UR not used and consequently closed to the outside.

In this case no refrigerating fluid nor heating fluid is required, so that the rectifying device according to this invention may just have a first separating flat plate 13, an undefined number of "rectify side" perforated flat plates 22 and 22.R in alternated sequence and a second separating flat plate 13.

DISTILLER DEVICE OR VAPOUR GENERATOR

In all distilling and rectifying ducts 48 shown in the front view of Fig. 15, a rich fluid mixture to be distilled enters the opening IL, the distilled vapour is expelled from the opening UV and the lean mixture is expelled from the openings UL. In this distillation and rectifying process the opening IV is not used and is therefore closed to the outside.

The boiling zones 32 extend from the lower opening levels US and UE up to the height of the upper openings IP and UV.

In this application, thermal exchange ducts made with the same kind of "rectify side" perforated plates 22 and 22.R are provided with the same type of ducts 49, but tilted by 180° around their horizontal axis in respect to how they are shown in Fig. 15; thus the heating fluid can enter openings IR and go out from openings UE.

ABSORBER DEVICE FOR ABSORPTION REFRIGERATING SYSTEMS

In the ducts 48, which in this case become absorption ducts, the lean mixture enters the opening IL and the vapour to be absorbed enters the opening UV, whereas the rich mixture flows out of the opening UL.

As regards the thermal exchange ducts wherefrom the heat generated by the absorption process has to be evacuated, these can be exactly as described for the above "Distiller Device or Vapour Generator".

OTHER APPLICATIONS

It is obvious that many other changes and applications are possible to the compact heat and/or matter exchange device according to this invention.

For instance, it is possible to obtain distiller or rectifying columns allowing vapour tappings in several zones, for instance to separate more substances from each other, the same as more than two thermal exchange zones with over two thermal carrier fluids can be foreseen, wherever for complex systems the available fluids can be used at their best under different temperature conditions in various cycle stages.

Such heat recoveries, also theoretically obtainable at present, are usually ignored due to the excessively high cost for the number of exchangers required. According to this invention, the simple way to obtain more thermal exchange zones (by adding further through holes) from one compact device alone makes the cost increase quite irrelevant.

Intermediate fluid heat exchangers can be obtained when due to safety reasons it is not appropriate for the two heat exchanging fluids to lick directly the opposite faces of one same wall. In this case, according to the known heat tubes technique, for instance a first fluid circulating in the ducts 44 can release heat to a second fluid circulating in the ducts 46 through an intermediate fluid continuously boiling and recondensing in the ducts

48.

Finally, the intimate contact being reached between the downflowing liquid phase and the rising vapour phase makes this invention particularly of interest for manufacture of chemical reactors in view of the wide surfaces obtained with the perforated flat plates of one of the types described above.

It is obvious, as previously described, that the "rectify side" perforated flat plates 22.R can be obtained from the "rectify side" perforated flat plates 22 simply rotating them by 180° in respect to their centre, the same as said "rectify side" perforated flat plates 22.R can be developed from a completely different design of said "rectify side" perforated flat plates 22. Obviously, the same conditions applies for the "exchanger side" perforated flat plates 35 and 35.R, provided that when overlapping all the plates mentioned above the through holes arrays 31, 44, 45, 46 provide for the contact zones 11.A and the through gaps 11.B and that opening continuity is warranted (IL, UL, IV, UV, IE, UE, IR, UR).

It is also obvious that all the through holes arrays mentioned above shall have holes with appropriate dimensions, spacing and distribution for the single processes and fluids, and that said holes arrays shall also consist of sets of holes with a different diameter and/or pitch within the frame of one same plate or various plates.

However, it should be pointed out that due to several thermofluid-dynamics requirements, such as thermal exchange performance or loss of acceptable charge, solutions can be reached not only changing, from time to time, the design of the through holes arrays 33, 44 or 46, but maintaining unchanged in many applications the design of the perforated flat plates 22 or 35, and changing their number and/or thickness when forming each duct 48 or 49.

Therefore, all distiller and rectifying devices described above can be substantially developed using just three elements, i.e.:

- "rectify side" perforated flat plate 22,
- "exchanger side" perforated flat plate 35
- separating flat plate 13

arranged in adequate laying patterns and inserted in alternate sequence to each other, all provided with eight openings IL, IR, UV, UR, IV, UE, UL, IE, either duly used or locked.

Finally, as shown in some examples, it is obvious that the easiness of manufacturing a complete distiller and rectifying device according to this invention also increases the selection freedom for the required materials and surface treatments of the components to a much higher extent than according to the present state of the art.

Claims

1. A heat and/or matter exchanger for fluids, comprising a plurality of flat plates (1,13) and a plurality of spacing elements (6,6R; 22,22R), said flat plates (1,13) together with said spacing elements (6,6R; 22,22R) defining one or more primary heat and/or matter exchange chambers for the flowing of a primary fluid, said flat plates (1,13) together with said spacing elements (6,6R; 22,22R) also defining one or more secondary beat and/or matter exchange chambers for the flowing of a secondary fluid, said primary chambers, which are connected between themselves and with the outside through a plurality of primary openings (IP,UP), and said secondary chambers, which are connected between themselves and with the outside by a plurality of secondary openings (IS,US), being inserted in an alternate sequence, characterized in that at least one of said chambers comprises two or more perforated flat plates (6,6.R; 22,22.R) acting as spacing elements, said perforated flat plates (6,6.R; 22,22.R) having each one some through openings (11; 31), staggered to each other, so that the overlapping of said perforated flat plates forms contact zones (11.A) and through gaps (11.B), where said contact zones (11.A) ensure both a thermal and mechanical continuity between the perforated flat plates (6,6.R; 22,22.R), and said through gaps (11.B) allow at least some empty spaces obtained by the through gaps (11) inside each perforated flat plate (6,6.R, 22,22.R) to intercommunicate.

2. A heat and/or matter exchanger according to Claim 1, characterized in that said openings (11.B) allow most empty spaces created by said through holes (11; 31) within each of said perforated flat plates (6,6.R; 22,22.R) to intercommunicate.

3. A heat and/or matter exchanger according to Claim 1 or 2, characterized in that said through holes comprise holes arrays (11; 31), which are interrupted near the edges of said plates (6,6.R; 31).

4. A heat and/or matter exchanger according to Claim 3, characterized in that said plates (6,6.R; 22,22.R) are provided with at least four main holes (7, 8, 9, 10), each to carry out said primary openings (IP, UP) and secondary openings (IS, US), two (8, 10) of said main holes being intersected by said through holes (11; 31) with the purpose of connecting between themselves said primary or secondary through gaps (11.B).

5. A heat and/or matter exchanger according to the previous Claim, characterized in that said main holes (7, 8, 9, 10) are located near the edges of said plates (6,6.R; 22,22.R).

6. A heat and/or matter exchanger according to Claim 4, characterized in that said main holes (8, 10) intersected by said through holes (11; 31) are

located at different heights on said perforated flat plates (6,6.R; 22,22.R).

7. A heat and/or matter exchanger according to Claim 1, characterized in that said perforated flat plates (6, 6.R) comprise first type (6, 22) and second type (6.R; 22.R) plates, said second type plates (6.R; 22.R) being obtained from said first type plates (6; 22) by 180° rotation on their plane.

8. A heat and/or matter exchanger according to Claim 1, characterized in that each primary chamber is separated by a secondary chamber through one of said flat plates (1; 13), said flat plates (1; 13) having each one at least a hole (2, 3, 4, 5) to ensure or interrupt said primary (IP, UP) and/or secondary openings (IS/US), so as to obtain the desired types of connection between said chambers and with the outside.

9. A heat and/or matter exchanger according to Claim 1, characterized in that at least some of said primary chambers and at least some of said secondary chambers comprise said perforated flat plates (6,6.R; 22,22.R).

10. A heat and/or matter exchanger according to the previous Claim, characterized in that said perforated flat plates (6,6.R; 22,22.R) as used in said secondary chambers are obtained from the perforated flat plates (6,6.R; 22,22.R) as used in said primary chambers by tilting them by 180° in respect to an axis of said plates themselves.

11. A heat and/or matter exchanger according to Claim 1, characterized in that said through openings (11; 31) comprise holes of variable shape, dimensions and pitch along the extension of one same plate (6,6.R; 22,22.R).

12. A heat and/or matter exchanger according to Claim 3, characterized in that said holes arrays (11; 31) are interrupted in such a way to eliminate some of said through gaps (11.B) in certain zones, so as to avoid certain openings to the circulating fluid.

13. A heat and/or matter exchanger according to Claim 1, characterized in that a plurality of said primary and/or secondary chambers comprise each one a plurality of said perforated flat plates (6,6.R; 22,22.R), since the number of perforated flat plates comprised in one of said primary or secondary chambers differs from the number of perforated flat plates comprised in another one of said primary or secondary chambers.

14. A heat and/or matter exchanger according to Claim 7 and 10, characterized in that it is obtained by stacking an appropriate number of said first type perforated flat plates (6; 22), which are adequately arranged in upright position or rotated by 180° on the plane or tilted by 180° in respect to an axis, or rotated by 180° on the plane and tilted by 180° in respect to an axis, where flat plates (1; 13) are inserted between said plates in adequate intermediate positions and on their ends.

15. A heat and/or matter exchanger according to any one of the previous Claims, characterized in that one or more of said perforated flat plates (6; 22) and/or separating plates (1; 13) has a different thickness from the remaining perforated flat plates (6,22) and/or separating plates (1; 13).

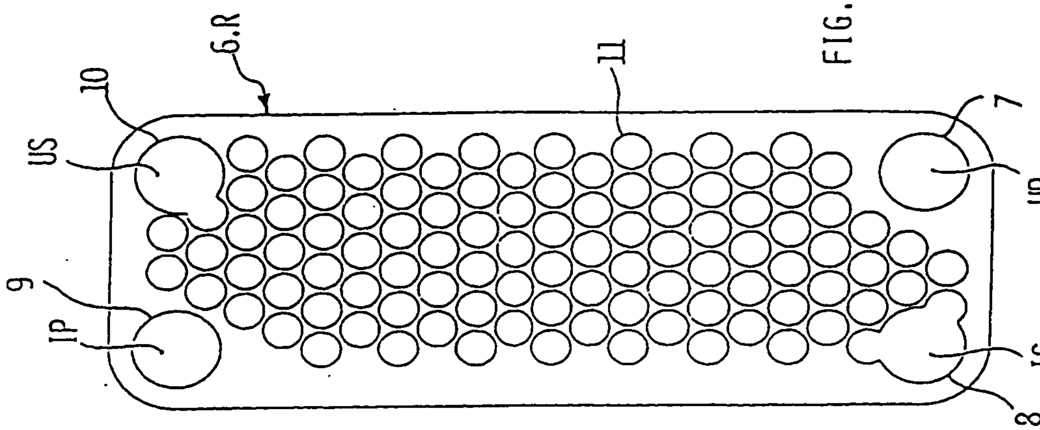


FIG. 3

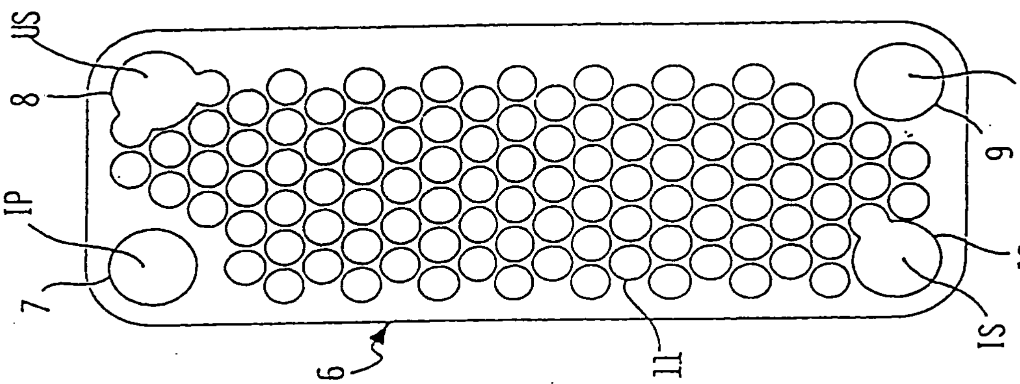


FIG. 2

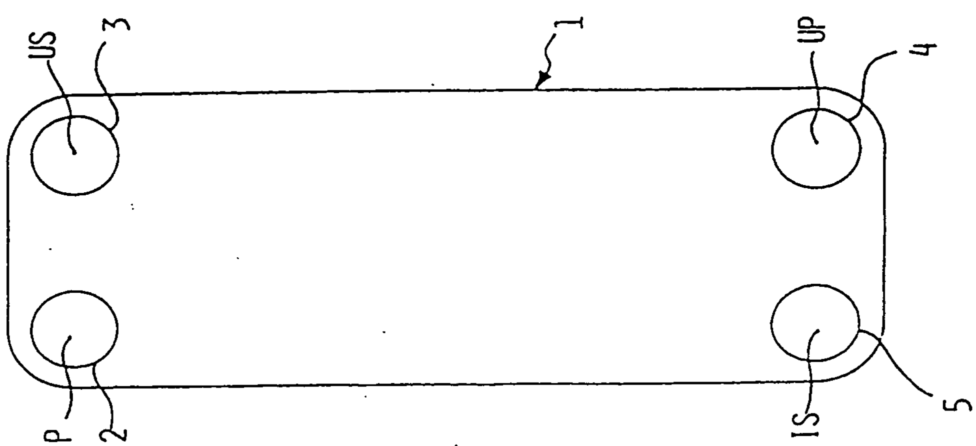


FIG. 1

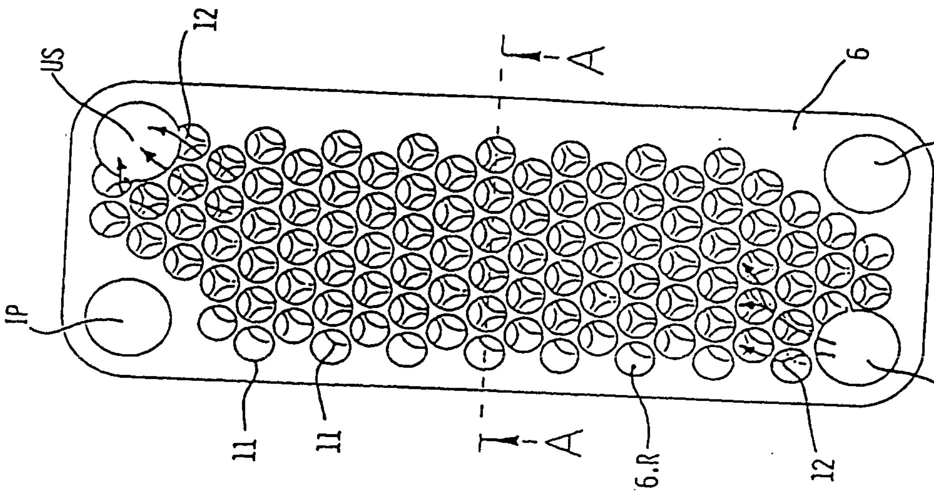

US
12
A
6
UP
IP
IS
11
11
A
6.R
12

FIG. 5

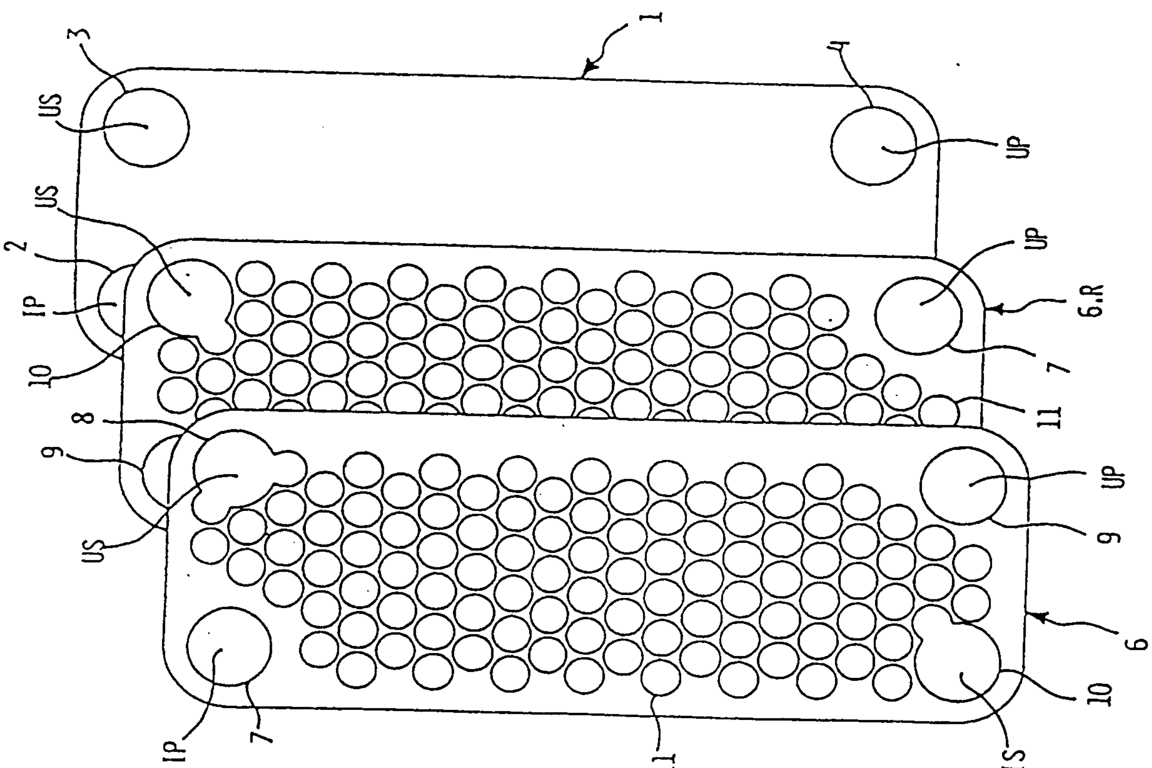

1
3
US
4
UP
US
2
IP
10
UP
6.R
7
11
8
9
US
UP
9
6
10
IP
7
11
IS

FIG. 4

FIG. 8

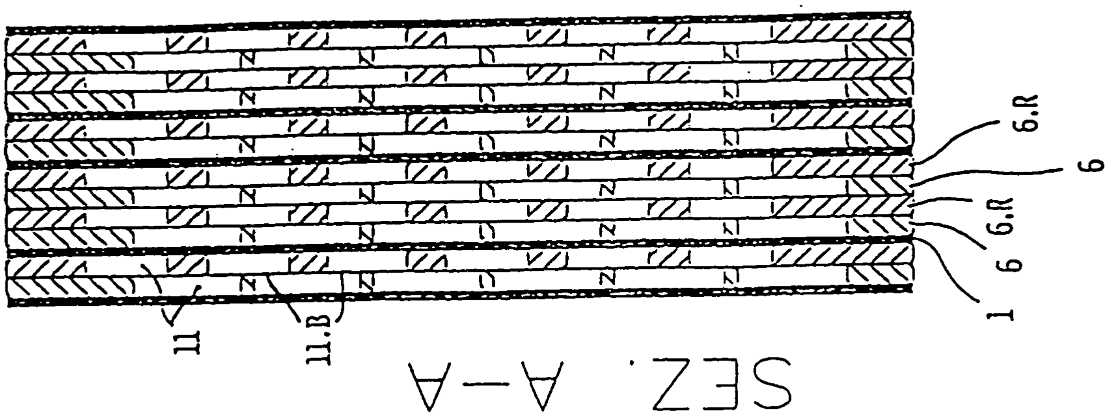
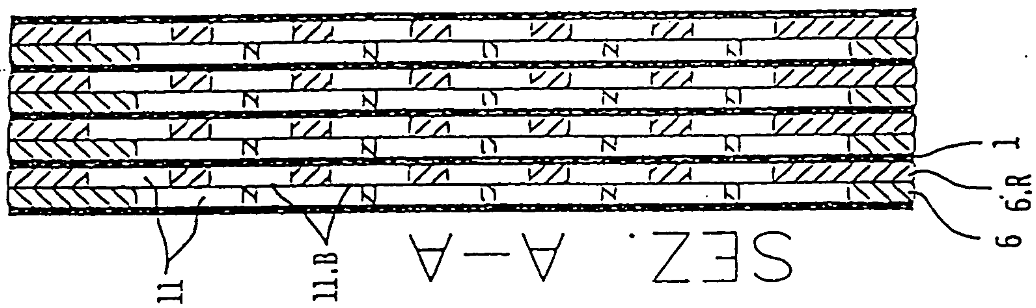


FIG. 7



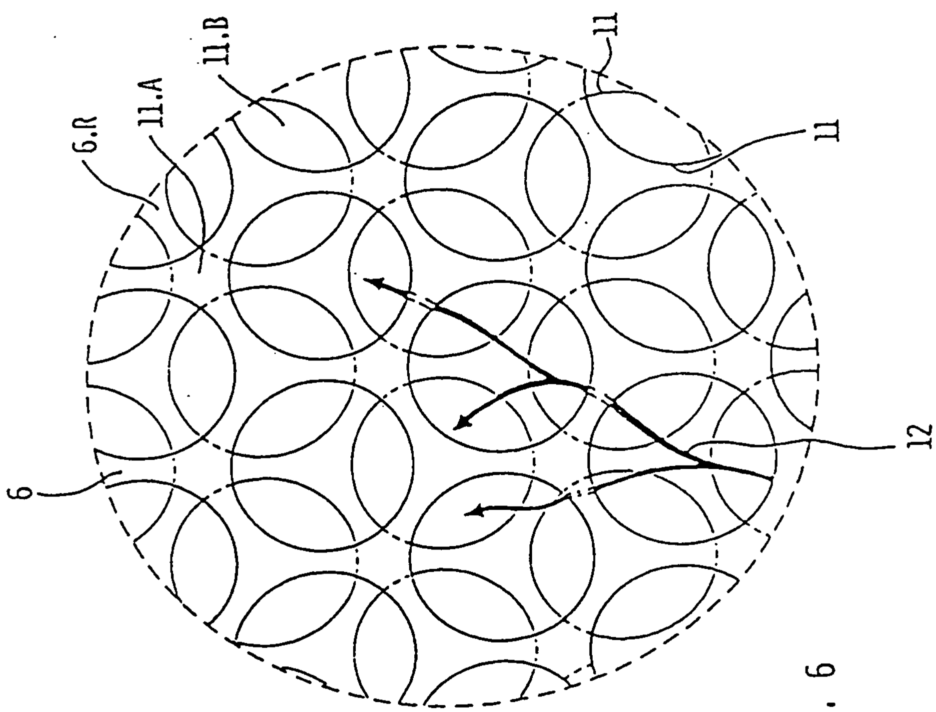


FIG. 6

FIG. 11

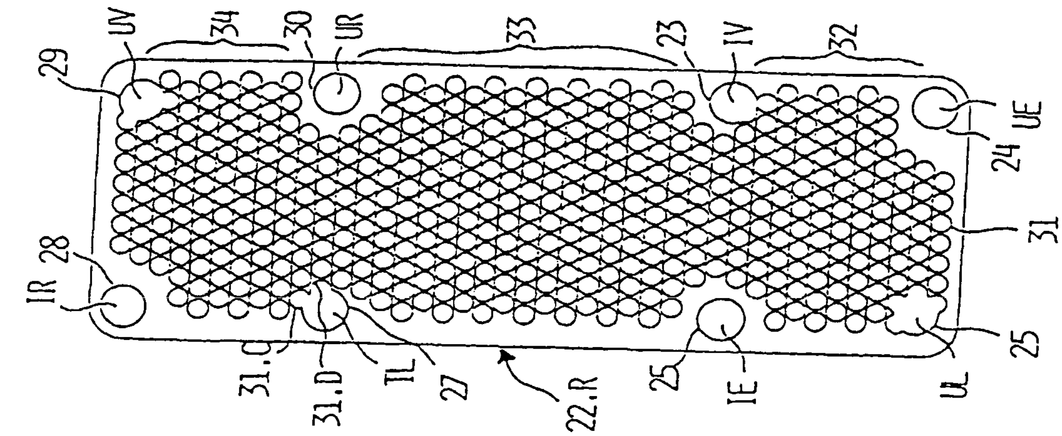


FIG. 10

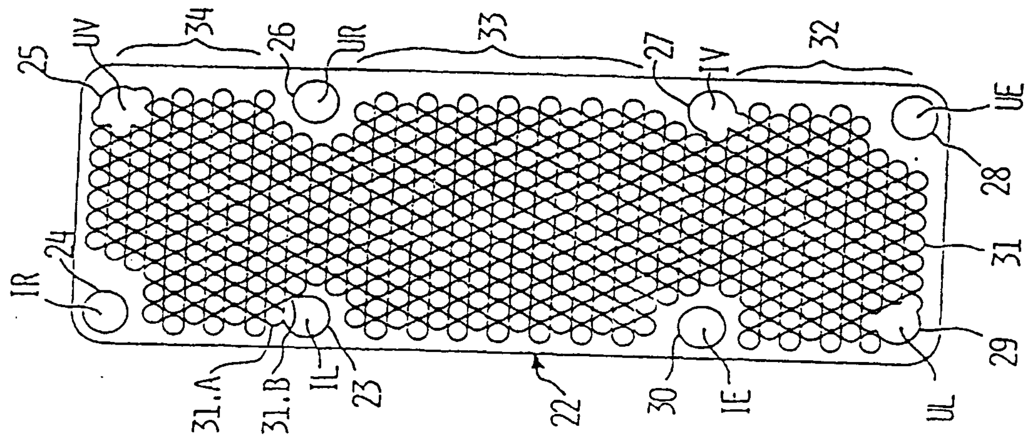
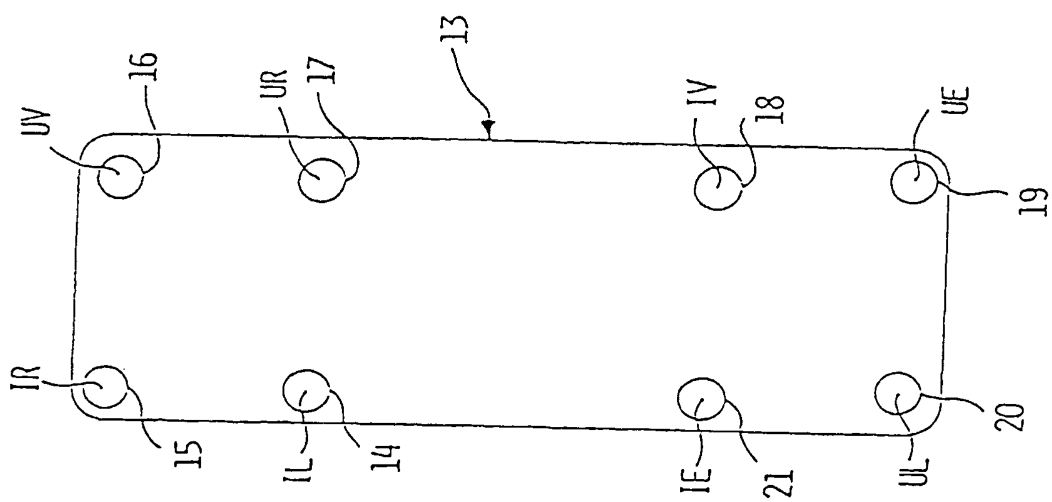


FIG. 9



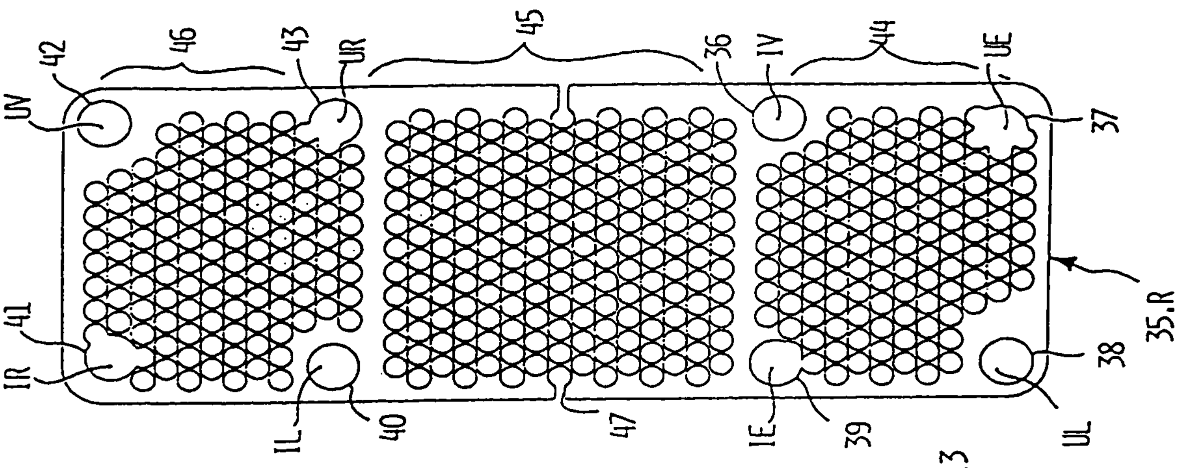
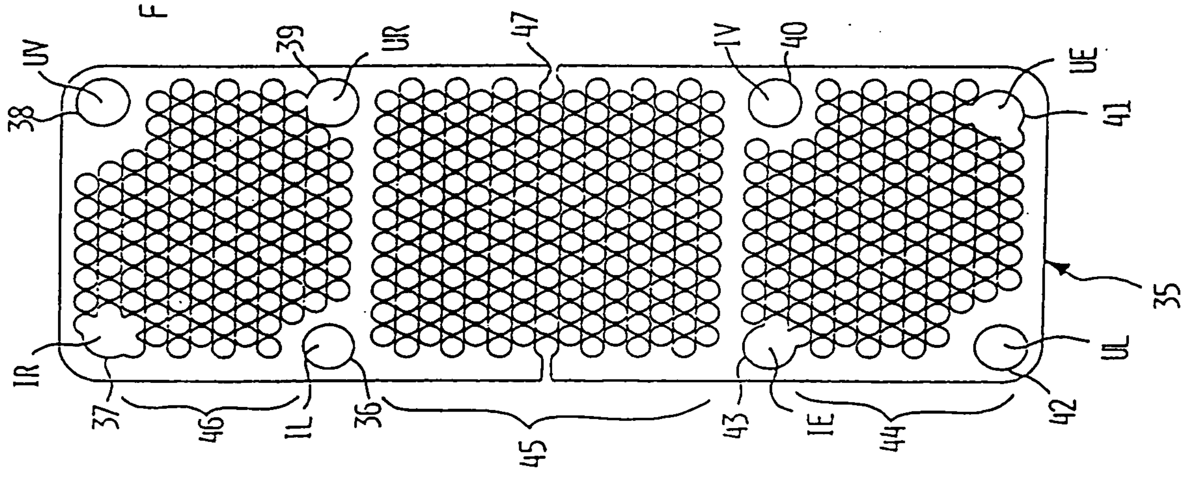

42
46
43
UR
45
36
IV
44
UE
UV
37
41
IR
IL
40
47
IE
39
UL
38
35.R

FIG. 13

FIG. 12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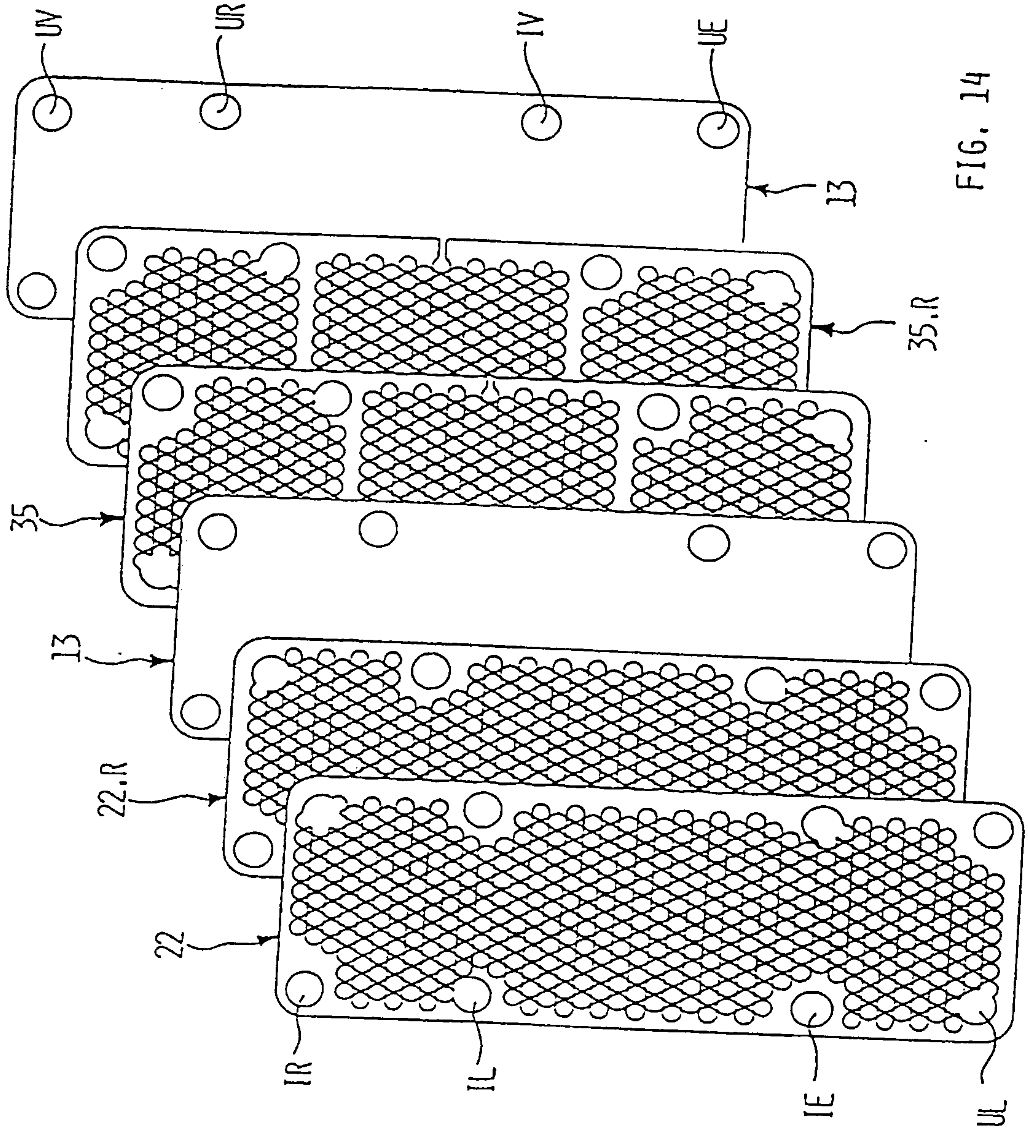
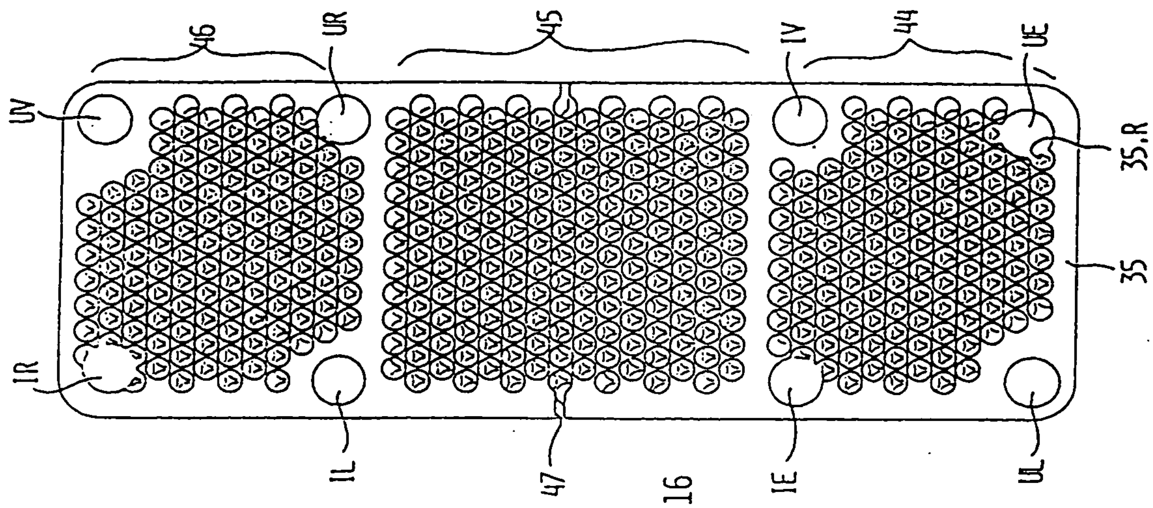


FIG. 14



46
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44
UE
UV
35.R
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IR
IL
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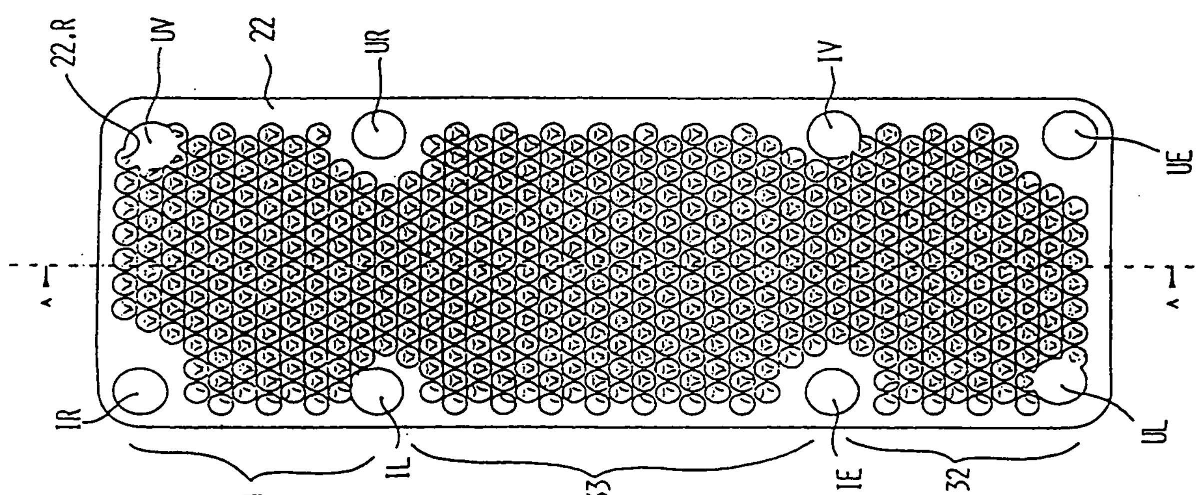
IE
UL

FIG. 16



22.R
UV
22
UR
IV
UE
IR
IL
IE
UL
34
33
32

FIG. 15

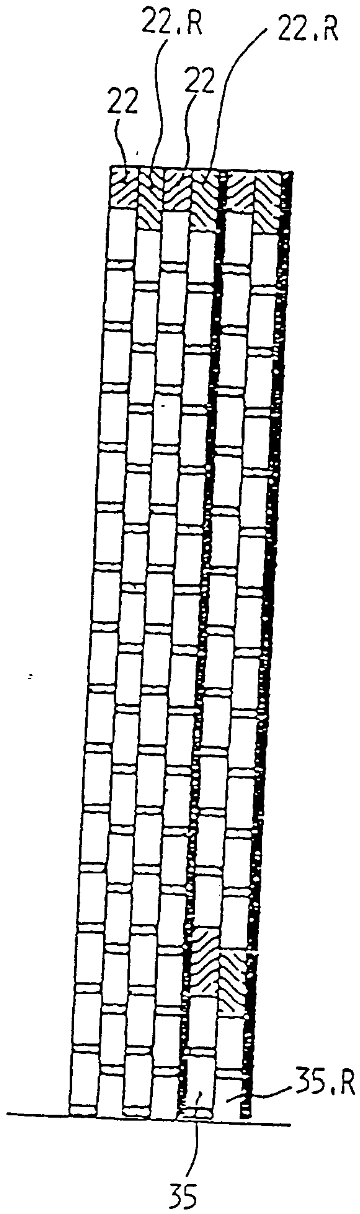


FIG. 17.A

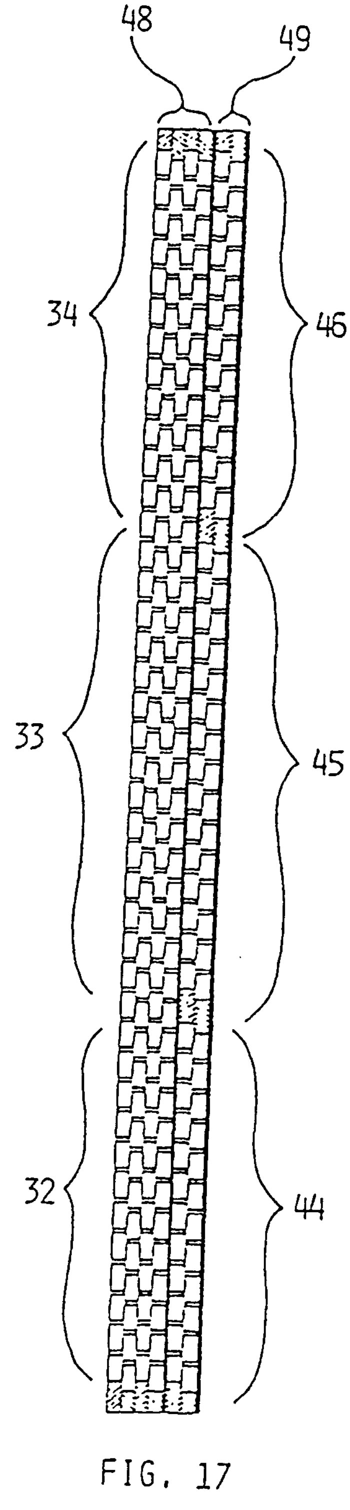
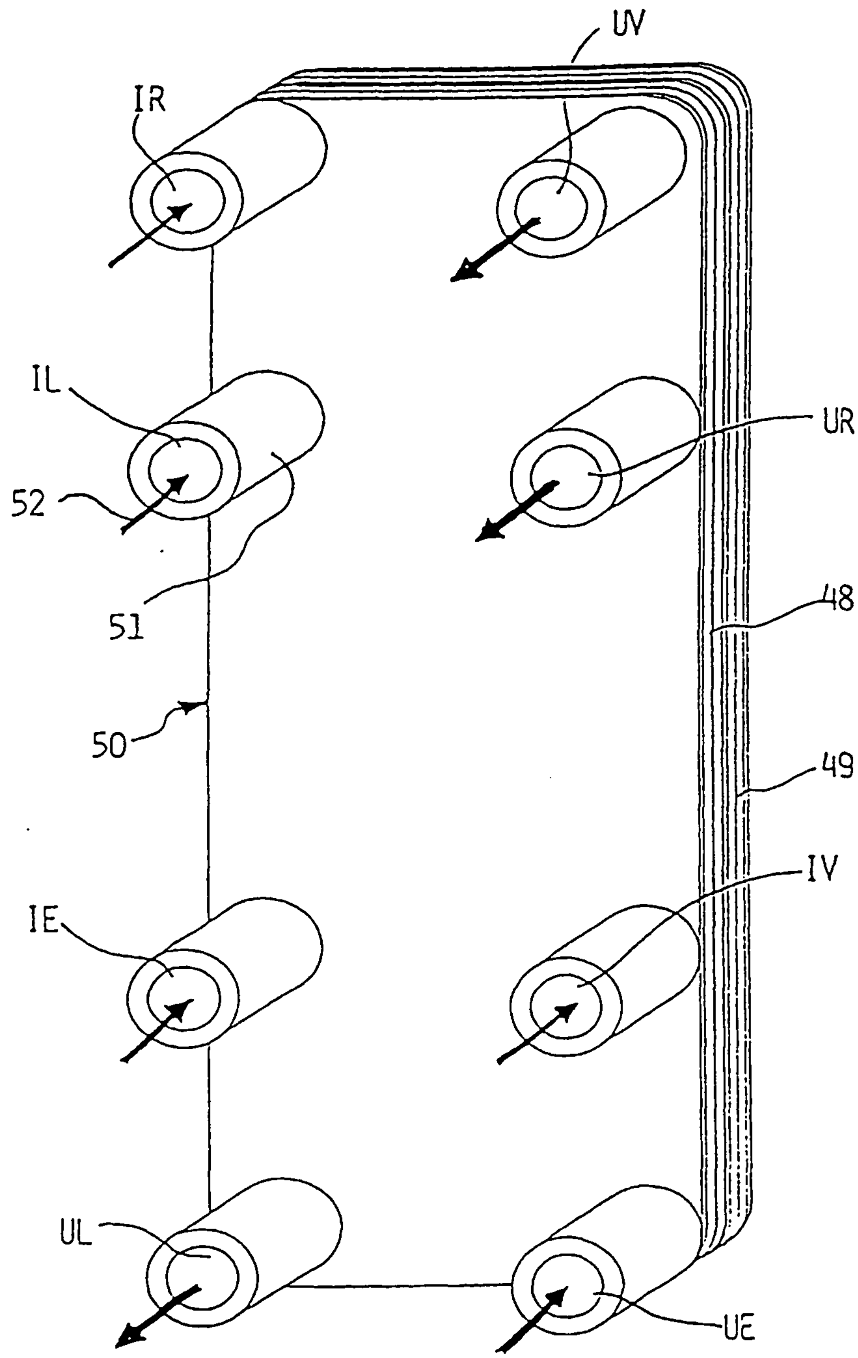


FIG. 17

FIG. 18



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 12 0289

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DE 42 38 192 A (HOECHST CERAM TEC AG) 19 May 1994 * the whole document *	1-3,5,8,9,11	F28F3/08 F28F3/02 F28F13/12
X	WO 90 13784 A (SECRETARY TRADE IND BRIT) 15 November 1990 * page 4, line 10 - line 36; figures 1,6A,6B *	1-3	
A	FR 2 290 646 A (COMMISSARIAT ENERGIE ATOMIQUE) 4 June 1976 * the whole document *	1	
P,X	EP 0 724 127 A (GIACOMETTI DIANA ;GIACOMETTI PAOLA (IT); PETRACCA GAETANA (IT)) 31 July 1996 * the whole document *	1-15	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
F28D
F28F
B01D
F25J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 March 1997	Zaegel, B

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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